NPIC/TSSG/DED-1676-69
20 June 1969

MEMORANDUM FOR : Chief, Development & Engineering Division

SUBJECT : Development of an Image-Processing Rationale

1. In partial fulfillment of the requirement to examine the field of image-processing and its potential applications to NPIC operations, I visited the following organizations to collect data relative to present image processing capabilities and future possibilities:

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a. Jet Propulsion Laboratories, Cal. Tech.
Pasadena, California (15 May 1969)

[redacted]

2. In addition to these visits, conversations on the same subjects were held during the Los Angeles conference of the Society of Photographic Scientists & Engineers (12-14 May) with the following individuals: 25X1

[redacted]

3. <u>Definition</u>

a. In the general case, image-processing is defined to mean any operation that transforms a given image into another image in a quantitative manner.

b. As used herin the term will be used to indicate optical and/or digital image transformation.

4. <u>Summary of the Visit to JPL</u>

a. <u>Introduction</u> - [redacted] Space Sciences Div., spent several hours explaining JPL's image-processing background, present hardware/software capabilities, objectives, and rationale. [redacted] works mainly with system hardware while his colleague, Dr. [redacted] handles software development.

JPL has developed hardware and techniques for digitally processing Ranger, Mariner, Apollo, and other NASA space imagery. Their capacity is not confined to space imagery, work on bio-medical imagery has also been performed. The primary reasons for employing digital as opposed to a coherent optical processor were the advanced state of the digital art when the program began, the greater flexibility available digitally, and the absence of the rapid processing time requirement.

b. <u>Objectives</u> - The two main technical objectives of the JPL program are:

(1) To improve images by removing photometric and geometric distortions, noise, and correcting for camera system MTF;

(2) To provide high quality information extraction options; e.g., contouring, edge enhancement, gray scale manipulation.

c. <u>System Review</u> - The JPL image-processing system (see fig 1) is comprehensive, sophisticated, time consuming, and expensive.

(1) Input/output

a. At present input/output options are limited to magnetic tape and a precision CRT; i.e., the Video Tape Converter and the Video Film Converter built by [redacted] Inclusion of a coherent-optical processor has been considered but not implemented. The same equipment is used for input and output operations. Images from film, hardcopy, and optical devices can be scanned, digitized and entered in the computer. Telemetry data can enter directly from magnetic tape.

b. Considerable emphasis has been placed on achieving a high signal-to-noise ratio. This is complicated whenever film is introduced. The resolution and image definition attainable are directly related to the signal-to-noise ratio.

c. JPL employs 1024 picture elements (pixels) per unit area scanned, as opposed to 64 employed by [redacted] and 256 by [redacted] In general the computer size is a major limiting factor. JPL requires the increased speed and quality because the unit area scanned (i.e., the largest area of an image that can be scanned at one time) at a film image resolution of 100 l/mm is only 2.5 mm^2 and the pictures produced must retain maximum definition. For a high quality system, using 6 bit digitizing and a sampling rate of 20,000 samples/sec, 50 seconds are required to input the 2.5 mm^2 unit picture area. From this example it can be seen that time becomes another limiting consideration - remember the computer processing and output time requirements have still to be added in. Images of larger areas are scanned in multiples of the unit area. 25X1

25X1

(2) The Computer

JPL employs an IBM 360/44 computer equipped with 4 tape decks, 2 disc drives, and other supporting components. Software to provide image enhancement, nonlinear transformation, spatial frequency transformations, and similar operations has been written. Fig. 2 lists potential application areas for digital image processing. No average estimate of processing time can be given since the duration of each operation will vary with image quality and the analysts judgment; however, times ranging from minutes to hours would not be extraordinary. The computer drives the display devices and controls peripheral components. Processing time is proportional to computer capacity.

(3) Display Console

This component of the JPL system is not yet operational. It will employ an IBM 2250 graphic display console with light pen. More commonly known as the interactive display console, it is this component that permits man's judgment to enter the image-processing sequence; e.g., the selection of a correction operation to be performed on a distorted image. Through the interactive display unit algorithms are constructed by trial and error. The input image is digitized processed and the algorithm recorded. The input and output images can be fed to the console so that before and after comparisons may be made.

(4) Discussion

a. The research in image processing at JPL has until recently been entirely sponsored by NASA. The National Institute of Health is presently sponsoring a project with NASA consent. [redacted] indicated it would be possible to accept projects from other Government 25X1

agencies. For example, JPL is looking for support to build a new high resolution scanner using an image disector tube and a CRT.

b. I viewed samples of image enhancement, change detection and amplification of small density differences. The processed imagery was noticeably improved. No processing of imagery similar to that viewed at NPIC has been done and experiments would be required to determine whether the electronic scanning used could retain adequate detail. In its present configuration it is several orders of magnitude
25X1 faster than the [redacted] optical-mechanical scanner. Of course, the latter has the higher resolution gained by trading off with speed. The [redacted] line-scan project may shed some light on this problem. 25X1

5. <u>Summary of the Visit to</u> [redacted] 25X1

a. <u>Introduction</u> - [redacted] 25X1
of the Mathematics & Evaluation Studies Department presented a detailed
25X1 briefing and equipment demonstration which covered the present and future
25X1 status of image-processing at [redacted] For convenience, their program was divided in two parts. Part one, the [redacted] 25X1
[redacted] includes a computer, an interactive display unit and the associated
25X1 hardware. Part two, the [redacted] includes 25X1
25X1 an automated coherent optical system in which the image of diffraction pattern may be viewed alternately, and a remote control console. The [redacted] 25X1
25X1 [redacted] system was designed and developed by [redacted] starting in 1961. In 1965 25X1
[redacted] submitted a proposal recommending their system be applied to the NPIC ATR program eventually awarded to [redacted] Since that time 25X1
[redacted] has been refined and automated. The entire program has been accomplished without external funding.

b. <u>Program Objectives</u> - The program has two primary objectives:

(1) to develop a rapid automated signature analysis capability with an adaptive learning network dependent, in part, on human intuition and recognition abilities.

(2) to develop applications in addition to analysis of images on film.

c. System Review

(1) Input

A coherent optical system was chosen as an input device because of its ability to handle or process large quantities of data rapidly; the input time and Fourier transformation are done at the speed of light. This approach is not as versatile as the digital processing in terms of the variety of transformations that may be accomplished (see fig 2) and unfortunately, noise is still a major problem. 25X1 The [redacted] illuminates film 0.6" in diameter with a laser beam. The areas viewed may be selected at random by an operator or preprogrammed in any sequence and controlled automatically by the computer. The diffraction pattern of the area on the film is formed optically in a precisely known position where it can be viewed by the operator or the photo tube. The output of the phototube is fed to the computer. Assuming, for the moment, an algorithm exists for this particular area, the computer will recognize the area (e.g., natural, man-made farm) and print a description on the graphic display unit. This entire sequence can occur in less than 10 seconds depending on the complexity of the area examined and the operator's experience. By comparison, just the input scanning phase of the JPL digital system requires about an hour.

(2) Computer (processor)

25X1 [redacted] employs an IBM 360-65 computer with a fast memory of 256K bytes and a lower speed large core storage of one million bytes, of which the [redacted] uses 400K. The 25X1 computer has six basic routines to handle the signature analysis operations. No enhancement, change detection or similar programs have been written at [redacted] since they are 25X1 already available from commercial and academic sources.

(3) Output

25X1 The [redacted] output can take two forms - video (IBM 2250 graphic display console) and printed (on computer paper). No picture is displayed, only a matrix listing the images scanned and their identification. It is at this station in the system that the human interaction comes into play. When an area of the film is viewed and not recognized by 25X1 [redacted] the operator is signaled on the display unit. He must then build an algorithm so that it will be recognized in the future. To do this, the operator views

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the picture and its diffraction pattern on the optical system ground glass and attempts to determine a unique correlation between the two using the basic computer routines. With experience an operator can find such
25X1 correlations. At [redacted] this has been accomplished for the natural, man-made agricultural categories and some sub-categories; e.g., aircraft, farms, residential areas. The algorithm building is iterative, intuitive and at this point essential. It can be time consuming, but once concluded, less than 1% wrong decisions are made.

d. Discussion

25X1 (1) The [redacted] system is operational. The [redacted] can be 25X1
25X1 purchased (for about [redacted] minus computer), rented, or used as a research tool on a contract basis. The [redacted] software 25X1
could also be purchased. [redacted] has been informed. 25X1

(2) The computer is interfaced with the optical system in a manner that permits the recording of the portion of the image the operator looks at, in terms of image coordinates and spatial frequency distribution, with the data collection occurring automatically. This approach could produce objective data concerning what the PI thinks is important and how he goes about interpreting the image; a kind of "TICOF" experiment within the image.

25X1 6. Summary of Visit to [redacted]

a. I received an update briefing on both of the [redacted] approaches 25X1
(optical and electronic) to the ATR problem from [redacted] He is 25X1
25X1 aware that image-processing will be employed to accomplish objectives beyond their immediate program goals as the technology is developed and feels [redacted] is in a good position to participate in any such effort. As might be expected, the techniques and much of the film handling equipment developed
25X1 by [redacted] for their present contract could be adapted to more general image processing tasks.

7. Summary of Visit to [redacted] 25X1

25X1 [redacted] Marketing Manager, and [redacted] (a systems 25X1
engineer) briefed me on a variety of information retrieval and analysis
25X1 systems built by [redacted] including the input/output equipment for JPL. The main item of interest was their laser scanner. It is a breadboard item at present, and has been under development for several years.

Problems have been encountered in maintaining two dimensional linearity; a curved filmed plane is currently used with a rotating prism controlling the beam. Only bar targets have been scanned to date. Though the present quality is much improved over that of a year ago, it does not appear to be high enough for NPIC application or to warrent support at this time. The primary reasons for pursuing laser scanning techniques are the high signal-to-noise ratio, rapid scanning rate and the large amount of energy available. A better estimate of potential value will be made after the [redacted] laser scanner capabilities have been determined. A briefing on this subject will be attended on 1 July 1969 at Wright Patterson AFB. 25X1

8. Miscellany

25X1 [redacted] described a new type solid state scanner using light sensitive phototransitors in a linear array. Resolution values approaching 40 cy/mm are being tested now, 20 cy/mm scanners have been developed. This approach holds great promise since scanning times of 100 ft/min are possible. A meeting with [redacted] will take place in July. 25X1

9. Conclusions

a. None of the image processing systems examined, as presently configured, will accomplish the tasks listed in fig 2 rapidly enough to be used in routine exploitation on-line, or off-line. The systems are essentially special purpose at this time.

b. There is a consensus among the individuals mentioned herein that:

(1) The technology necessary to adapt current image processing techniques to provide a highly automated, rapid, PI aid exists - only the funding is lacking.

(2) Internal funding will not be adequate to develop the hardware and software required.

(3) A system which meets the criteria of rapid and versatile operation will require a variety of input/output options, a large central computer, and a human interactive element.

(4) The time to start is now.

25X1 c. The [redacted] has excellent potential as a tool in experiments designed to bridge the subjective-objective measure gap. I am making a technical evaluation of this idea.

d. There are other image-processing systems that should be examined before specific recommendations concerning their application in NPIC are made: these include [redacted] The efforts being pursued by these organizations will contribute to the development of a comprehensive image processing program as opposed to a series of small loosely related contracts.

e. The solid state scanner is worth a very close look. It could result in a breakthrough solution to the long input time problem in digital processing systems. It has many potential advantages over the laser scanner.

10. <u>Future Plan of Action</u>

a. June - July 1969

(1) Complete the survey of firms listed in the conclusions.

(2) Recommend preliminary programs as necessary.

b. <u>August - September 1969</u>

Prepare a comprehensive image-processing program consistent with NPIC objectives and the technological state-of-the-art.

[redacted]
TSSG/DED

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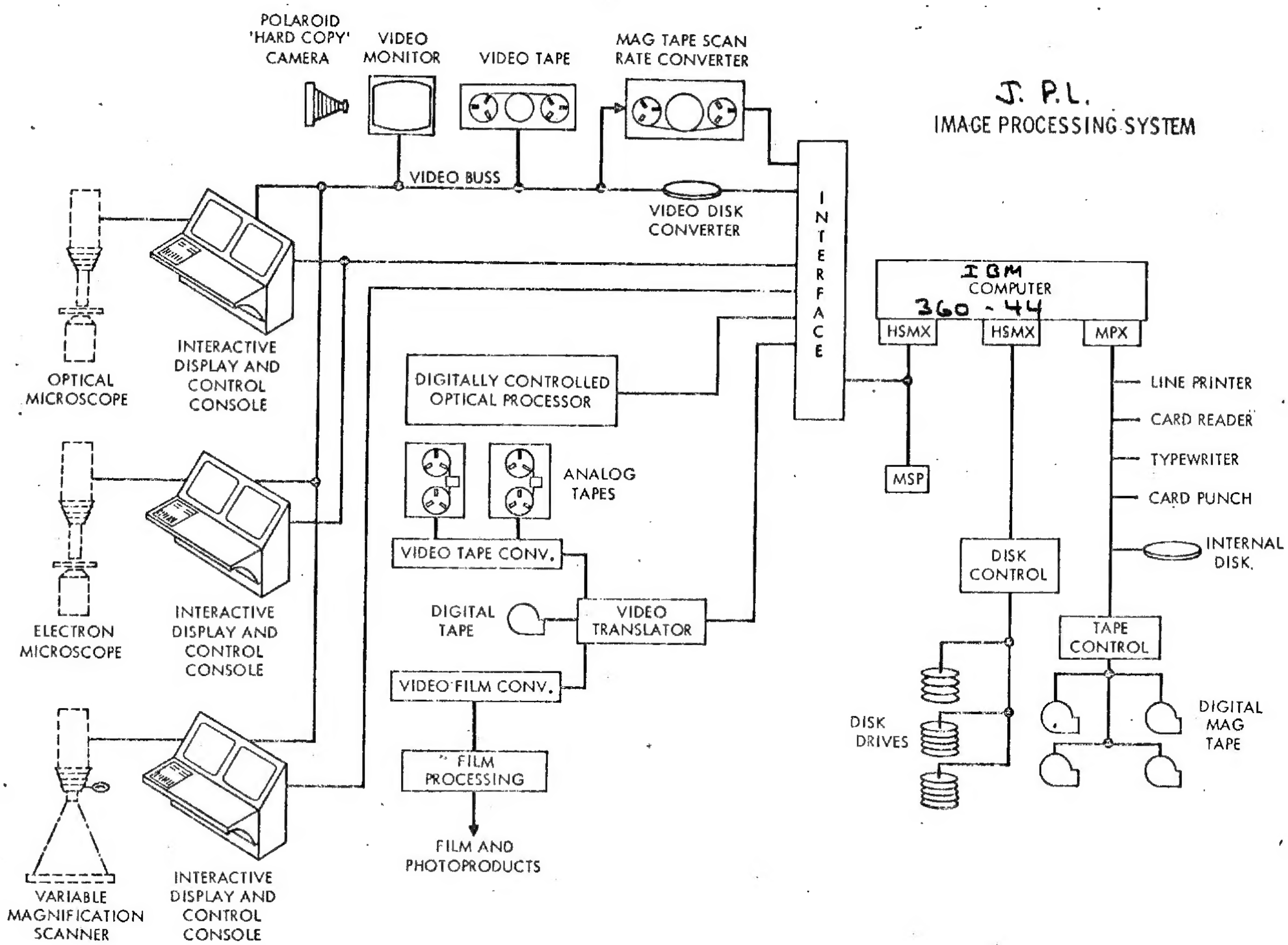
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OPTICAL MICROSCOPE
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DIGITALLY CONTROLLED OPTICAL PROCESSOR
ANALOG TAPES
VIDEO TAPE CONV.
DIGITAL TAPE
VIDEO TRANSLATOR
VIDEO FILM CONV.
FILM PROCESSING
FILM AND PHOTOPRODUCTS
ELECTRON MICROSCOPE
INTERACTIVE DISPLAY AND CONTROL CONSOLE
VARIABLE MAGNIFICATION SCANNER
INTERACTIVE DISPLAY AND CONTROL CONSOLE

FIG. 1.

TABLE 1. *Some uses for image processing*

Area	Technique	Use
Generation	Computer-originated	Test targets
		Graphical displays
	Computer substitutions	Insert windows in pictures
		Insert good data for bad
Intensity manipulation	Intensity calibration of systems	Photometry
	Nonlinear lookups	Film curve corrections
		Grey scale alterations
	Chromaticity calculations	Color shift, balance, alteration
Geometric manipulation	Geometric calibration of systems	Good geometry needed for stereo
	Reprojection	Convert slant pixels to ground projection
	Overlay match of 2 pictures	Rubber sheet stretching
	Independent X and Y adjustments	Aspect ratio corrections
Spatial frequency operations	Spatial high frequency boost	Correct for detail losses in system
	Spatial low frequency reduction	Minimize broad-brush shading
		Remove effects of glare
	Single frequency filtering	Remove coherent noise
Analysis	Fourier transform	Analysis in spatial frequency plane
	Image light distribution	Star cluster analysis
	Pattern extraction	Counting blood cells, automobile, stars, etc.
		Analyzing shapes of objects
	Convolution	Filtering, correlation
Multi-picture	Subtraction	Change detection
		Stero information extraction
	Addition	Averaging, noise removal
	Multiplication	Spatial domain filtering
	Division	Normalizing

Fig. 2.